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ROUTINE SURVEILLANCE OF RADIOACTIVITY AROUND NUCLEAR FACILITIES

Public Health Service
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December 1966

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Radiological Health

ROUTINE SURVEILLANCE OF RADIOACTIVITY AROUND NUCLEAR FACILITIES

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

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ROUTINE SURVEILLANCE OF RADIOACTIVITY AROUND NUCLEAR FACILITIES

December 1966

Interlaboratory Technical Advisory Committee
Report No. 1

by the

Subcommittee on Environmental Surveillance

Dr. Lloyd R. Setter, Chairman
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Washington, D.C. 20201

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FOREWORD

This report is the first in a series issued under the auspices of the Interlaboratory Technical Advisory Committee (ITAC). The ITAC is an advisory committee of the Division of Radiological Health composed of technical personnel of Division laboratories and other technical personnel in the Department who have expressed an interest in laboratory activities related to the measurement of radiation in the environment. At its founding in 1960, ITAC was charged with the following purposes and objectives:

1. To serve as a forum for technical people to discuss technical problems and to stimulate thinking in radiological health;
2. To provide a broad base for the exchange of information on laboratory techniques and sampling methodology required for the determination of radioactivity levels in people and the environment;
3. To develop technical guidelines for laboratory operations;
4. To provide scientific evaluation of laboratory methodology and recommendations to guide the development of standard or improved techniques by the laboratories represented on the committee;
5. To provide recommendations to promote the standardization of reporting units, methods, and procedures, as well as the degree of accuracy and precision of data;
6. To suggest specific areas of scientific and technical need and interest;
7. To promote, through meetings and reports, uniformity of effort and coordination of laboratory activities.

This report was prepared by the ITAC Subcommittee on Environmental Surveillance. The aim was to provide a concise, comprehensive, and practical guide to the planning, operation, and evaluation of an effective surveillance program for public health agencies. Although the literature contains a large amount of material, such a guide has not been available for this important phase of radiological health.

As would be expected, many people played a role in the success of this project. Particular credit is due the many experts outside the

Public Health Service with whom the subcommittee consulted and who gave so generously of their time to review various drafts of the report and to offer comments and suggestions for its improvement.

James G. Terrill, Jr.

JAMES G. TERRILL, JR.
Deputy Chief
Division of Radiological Health

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ABSTRACT

This report is a concise, comprehensive, and practical guide for planning, operating, and evaluating the effectiveness of a program for routine surveillance of radioactivity around nuclear facilities. Included are references to regulations and guides for evaluating releases from such facilities, and commentary on the nature and types of wastes to be anticipated; their fate when released to the environment; and recommended procedures for sampling the air, water, milk, food, biota, soil, and people for resulting contamination.

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ROUTINE SURVEILLANCE OF RADIOACTIVITY AROUND NUCLEAR FACILITIES

December 1966

INTRODUCTION

This report is a guide and a summary of current expert opinion on procedures for routine environmental radiological surveys around certain nuclear facilities. These facilities include all nuclear activities that produce or process radioactive materials in relatively large quantities. Examples are nuclear reactors, fuel processing plants, mining and milling operations, and certain industrial applications. Smaller users of radioactive materials, such as hospitals and research establishments, are not included because regular surveillance of their surrounding environment is usually not warranted.

Surveillance may be defined as a continuing, systematic study of the environment to determine its radiological characteristics, to ascertain the identity and concentrations of the radioactive materials in the various phases of the environment, and to identify probable sources. The surveillance program requires reliable methods for monitoring air (gases and particulate matter), precipitation, surface and ground water, soil and stream sediments, milk and other food, biota not normally considered as human food, and people. The data are used to estimate the extent of the public health hazard and serve as a guide for effective remedial action where action is necessary.

The evaluation subcommittee recognized the great diversity of industrial nuclear operations and the consequent variations in the kind and intensity of surveillance activities which would be considered adequate. The subcommitte recognized that certain nuclear operations require only a minimum of health and safety precautions in the plant to assure the adequate control of radioactivity, and that other operations require detailed surveillance to meet public health needs and to meet public relations needs. In actual practice the extent of surveillance and the particular environmental media to be sampled must be evaluated for each type of plant.

The subcommittee decided to start with general guides rather than detailed guides for specific installations. Guides for specific types of nuclear facilities, such as power reactors, or types of surveillance, such as the emergency surveillance following an accident, are under consideration.

The subcommittee reviewed each of the phases of the environment in terms of its acting directly or indirectly as a source of human radiation exposure. Although specific recommendations are given for sampling air, water, food, biota, soils, and precipitation, it should be emphasized that extensive surveillance of the major portion of these segments is necessary in only a few instances (*1*). For example, if an agency of a State receives regular reports on the extent, mode, and composition of wastes released by a given establishment, and these data indicate that the wastes are of minor concern, an adequate surveillance program may include only the yearly assay of radionuclides in the principal human dietary items produced in the area. On the other hand, installations releasing larger volumes of more significant wastes would require correspondingly greater surveillance. In essence, then, the extent of an adequate surveillance program will depend upon the magnitude of the potential hazard in relation to what is known concerning the behavior and distribution of the given waste components, considered in relation to the critical segment of the population exposed to the potential hazard (*2*).

GUIDES AND STANDARDS

The Atomic Energy Commission (*3*) and some State and local governments provide regulatory controls for the safe operation of nuclear facilities. The general philosophy for applying these controls is that all unnecessary radiation exposure to people should be avoided. This approach has been repeatedly endorsed by the Federal Radiation Council (*4, 5*) and the National Committee on Radiation Protection [1] (*6*).

Other regulations and guides for interpreting radiological data are available from four principal sources.

The Federal Radiation Council (FRC) has established intake values for strontium 90, strontium 89, iodine 131, and radium 226 (*4, 5*). A graded scale of action is recommended when the intake from each of these radionuclides reaches a prescribed level. These guides have been incorporated in AEC regulations on the quality of

[1] The new name of this organization, as recently approved by Congress, is the National Council on Radiation Protection and Measurements.

plant effluents discharged into water courses and the atmosphere (*7*).

The Public Health Service (*8*) has recommended limits on the concentration of strontium 90 and radium 226 in drinking water on the basis of the guidance provided by the FRC. These standards also include a recommended upper limit of gross beta activity in drinking water in the absence of alpha emitters and strontium 90.

For guidance on the interpretation of data on radionuclides other than those above, the International Commission of Radiological Protection (ICRP) (*9*) and the National Committee on Radiation Protection (NCRP) (*6*) have recommended maximum permissible concentration (MPC) values for water and air for occupational exposures. These MPC's may be applied to the general population with suitable reductions. Similarly, these values may be applied to food products with caution. In terms of analytical capability, laboratories responsible for analyzing samples for purposes of environmental radiation surveillance should be able to measure radionuclide concentrations equal to about 10 percent of the recommended standards, and to measure the recommended standards with a precision of 10 percent or less at the 95-percent-confidence level. In the case of FRC guides, this criterion is applicable at or above the midpoint of Range II. However, since the FRC guides are based on total intake, consideration must be given to the importance a fractional part of the diet contributes to the whole. As a first approximation, it may be assumed that the total diet rarely exceeds 4 kg/day and that no single food item would on the average exceed 1 kg/day.

CHARACTERISTICS OF NUCLEAR WASTES

Nuclear wastes may be gaseous, liquid, or solid, and may be purposedly or inadvertently discharged as atmospheric or liquid effluents, or disposed of, with or without treatment, as solids (organic and inorganic) for burial (*10*). In a nuclear facility such as a 5-megawatt training reactor, the fuel is encapsulated and, consequently, the quantities of radioactive waste are usually minimal, arising primarily from leaks through the encapsulation, or from being generated by neutron bombardment of chemical elements in the primary coolant. This condition is also true for pressurized water reactors (PWR) and boiling water reactors (BWR) under normal operating conditions. Wastes from uranium and thorium mining and milling operations may be toxic due to chemicals or daughter products such as radium 226 and, therefore, surveillance of waste discharges may be required (*11–14*).

Wastes from spent fuel recovery plants require special attention since megacurie quantities of mixed fission products in gaseous, liquid, and solid state undergo extensive chemical processing and handling (*2, 10, 15–18*).

Nuclear and Radiological Characteristics

Table 1, adapted from an FAO report (*15*), indicates the fission products whose yields, half-lives, and biological properties, are important in environmental contamination. Table 2 contains information on the biological properties for a number of these nuclides, as well as for certain nuclides that are either naturally occurring, result from neutron activation, or are used as reactor fuels. In many instances, information on the types and quantities of materials being handled in a given facility is available through licensing authorities. This information can be invaluable in estimating potential releases to the environment and in establishing appropriate sampling and analytical protocol.

Table 1. Fission products important because of yield and half-life (*15, 19*) (Atom yield >0.5 percent; half-life >10 hours)

Chain atomic weight	Fission yield (atom percent of chain) [a]	Nuclide and half-life	Total activity (kCi/MW) [b]
85	0.3	Kr (10.6y)	
89	4.6	Sr (51d)	0.2
90	5.1	Sr (28y)—Y (64.4h)	39
91	5.4	Sr (9.7h)—Y (57d)	1
95	6.3	Zr (65d)—Nb (35d)	45
97	5.9	Zr (17h)	53
99	6.1	Mo (66h)	19
103	3.4	Ru (40d)—Rh (57m)	40
106	0.5	Ru (1.0y)—Rh (30s)	28
129	0.9	Te (41d)	2
131	3.1	I (8.1d)	3
132	4.0	Te (78h)—I (2.3h)	24
133	6.3	I (21h)—Xe (5.3d)	30
135	6.0	I (6.7h)—Xe (9.2h)	24
137	6.2	Cs (30y)—Ba (2.6m)	4
140	6.1	Ba (12.8d)—La (40h)	1
141	6.0	Ce (33d)	48
143	5.0	Ce (33h)—Pr (13.7d)	51
144	5.0	Ce (285d)—Pr (17.5m)	28
147	2.9	Nd (11.1d)—Pm (2.6y)	25
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[a] Slow neutron fission of uranium 235.

[b] Kilocuries (excluding daughter activity) of fission product produced per megawatt of energy after operating a nuclear reactor for 1 year followed by 1 day of decay.

Fate of Radioactive Releases

The three principal avenues of radioactive releases to the environment are: (a) Atmospheric releases, usually from elevated stacks, (b) liquid releases into surface streams or the ground, and (c) solid wastes, including structural material, equipment, paper, cloth, and so forth, and liquids absorbed in concrete or other matrix. All of these solid wastes may be buried or stored in an innocuous state.

Table 2. Biological properties of some radionuclides of importance to the contamination of human food (*15*)

Radionuclide and source	Critical organ	Fraction from G.I. tract to critical organ [a]	Effective half-life (days)
Fission products:			
^{131}I	Thyroid	0.3	7.6
^{133}I	Thyroid	0.3	0.9
^{135}I	Thyroid	0.3	0.3
^{132}Te	G.I. tract	[b]	[b]
^{137}Cs	Total body	1.0	70
^{89}Sr	Bone	0.2	50
^{90}Sr	Bone	0.2	6.4×10^3
^{140}Ba	Bone	0.03	11
^{103}Ru	G.I. tract	[b]	[b]
^{106}Ru	G.I. tract	[b]	[b]
Rare earths [c]	G.I. tract	[b]	[b]
Neutron activated:			
^{3}H	Body tissue	1.0	19
^{14}C	Fat	0.5	12
^{24}Na	Total body	1.0	0.6
^{32}P	Bone	0.37	14
^{41}A	Lung	–	0.08
^{55}Fe	Spleen	2×10^{-3}	390
^{59}Fe	Spleen	2×10^{-3}	42
^{60}Co	Total body	0.3	9.5
^{65}Zn	Liver	0.035	66
Mixture [d]	G.I. tract	[b]	[b]
Naturally occurring:			
^{226}Ra	Bone	0.15	1.6×10^4
^{228}Th	Bone	7×10^{-5}	690
Transuranic elements:			
^{239}Pu	Lung	–	[e] 365

[a] Assuming that the radionuclide occurs in soluble form.

[b] Only an extremely small fraction is absorbed into the body from the gastrointestinal (G.I.) tract. Therefore, the dose received by the G.I. tract during passage of the radionuclide is the limiting consideration.

[c] Rare earths ^{141}Ce, ^{144}Ce, ^{143}Pr, ^{147}Nd, ^{147}Pm, also ^{91}Y and ^{95}Zr.

[d] A mixture of other activation products such as ^{51}Cr, ^{54}Mn, ^{56}Mn, ^{58}Co, ^{64}Cu, and ^{65}Ni may be present.

[e] Reference *20*.

The fate of a release to the atmosphere is least predictable. For this reason it is most desirable to limit atmospheric releases to those which would be adequately dispersed. Releases of particulate or gaseous radioactive material, whether combined with inert local atmospheric particulates or not, are subject to physical and meteorological phenomena such as diffusion, sedimentation, inversion, advection, and wind movement. Normally, the releases are dispersed and diluted with little or no detectable deposition on the ground. However, atmospheric conditions may cause the plume of an effluent to reach the ground and thereby cause animal or human food contamination principally by impinging radioactivity on plant surfaces. Similarly, conditions of topography and the coincidence of precipitation may help to increase the deposit of unusual amounts of airborne waste in localized areas on soil or plant tissue where it may cling or be metabolized through, above, or below ground parts, and be deposited in the tissue, fruit, or seed used for animal or human consumption.

Insoluble radioactive matter from dry or wet deposition such as the relatively inert rare earth compounds would be expected to behave like soil particles of comparable size under the action of erosion, runoff, and so forth. Radionuclides which are soluble in precipitation or soil moisture may migrate with the water or react with the soil matrix. Ruthenium, for example, tends to migrate whereas cesium tends to be immobilized, in particular, by illitic clay (*21*).

The fate of radioactive waste discharges into surface water is more readily predictable than those into the atmosphere, and discharges into streams are usually more predictable than those into estuaries, large rivers, and impoundments. Streams subject to a rapid change of flow tend to vary rapidly in chemical and physical quality, particularly in the concentration of suspended solids. Similar changes may occur in large rivers but usually the changes are not as great nor as rapid. To a large degree, the treatment of the waste and the physical and chemical character of the stream determine the effect on the ecological system and the fate of radioactive releases (*22*).

Generally, a high content of suspended solids promotes the adsorption of soluble and insoluble radionuclides. Experience indicates that whereas clay particulates usually have substantial ion exchange capacities, living organisms and, particularly, dead organic matter have an avidity for adsorbing most radionuclides. Aquatic organisms often exhibit specificity in the concentration of some radionuclides (*23*); for example, zinc 65 accumulates in the muscle tissue of oysters (*24*).

Most streams revert to reaches or impoundments where suspended matter settles. Under these conditions, particularly if the organic fraction is subject to putrefaction, the anerobic conditions usually

favor the re-solution of radioactivity followed by a new cycle of adsorption and sedimentation as the river water moves seaward.

Brackish water causes greater sedimentation of general pollutants than fresh water. This tendency may be expected to apply also to radioactive pollutants and is of significance since it may affect the radionuclide content of shellfish used for human food.

The concern over radioactivity in surface water is twofold. A fraction of radionuclides may be in the dissolved state and may not be removed by conventional water treatment processes. These radionuclides may be ingested through domestic water used for drinking or culinary purposes. Another fraction, which may have been in either a suspended or dissolved state, may be ingested through the food chain if fish or shellfish from these waters are used for human consumption, or if the contaminated water is used for the irrigation of food crops.

Solid wastes properly packaged, handled, and buried with adequate shielding in restricted areas with control of leachings require minimum surveillance. Consideration should be given, however, to the surveillance of ground water sources subject to uncontrolled leachings from burial areas.

SURVEILLANCE OF THE ATMOSPHERE

Guides

The AEC regulations stipulate the concentration of specific radionuclides or limit the concentrations of a mixture of radionuclides in the total discharge to the atmosphere (*3*). Generally, these concentrations released to unrestricted areas are the equivalent of 10 percent of the MPC limits for occupational exposures for a 168-hour week (*6*). In the absence of alpha emitters and a few beta emitters, such as strontium 90 and iodine 129, the average concentration of unknown radionuclides of concern is 100 picocuries per cubic meter. On the other hand, alpha emitters, such as plutonium 239 are of concern at an average concentration of 0.06 pCi/m^3, and one of the most important beta emitters, strontium 90, is of concern at an average concentration of 30 pCi/m^3. Radioactive iodine is of special importance since this element is readily concentrated by human thyroid when inhaled or ingested. An intake in excess of 100 pCi of iodine 131 per day falls in Range III of the FRC Guide (*4*).

The above guides are useful in the development of appropriate testing procedures. It is generally more efficient to utilize rapid screening

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techniques such as gross alpha, gross beta, and gamma measurements for routine samples. These analyses may then be supplemented by the measurement of specific radionuclides of concern in composite samples covering a period of weeks or months.

Sampling

The most efficient and economical surveillance may be a cooperative plan designed by industry and the public health authority for sampling and monitoring effluent releases. The records of analytical results are made available routinely to industry and the public health authority. The latter is also notified of unusual or unplanned releases. Occasional unscheduled independent sampling and testing of plant effluents by the public health authority may also be advisable on a minimum scale to fulfill legal obligations. Such a cooperative arrangement could drastically reduce the routine field sampling and testing judged necessary by industry, the public health authority, or both.

The choice of sampling equipment, method of sample preparation, and counting instrument depend on the composition and quantity of radioactive waste to be released, the media affected, the biological importance of waste constituents and such factors as sampling frequency, accessibility of power, and economic considerations. When the stack effluents have been filtered, there may be a problem with gases such as krypton 85, tritium, tritium oxide, argon 41, radioactive iodine and possibly the activation products nitrogen 13, nitrogen 16, and oxygen 19. The problem is one of external radiation exposure for most of these radionuclides. Dosimeters, such as thermoluminescent devices (*25*), or gamma-sensitive photographic film (*26*), provide means of measuring doses and checking safety predictions. The release of krypton 85 from reactor operations is expected to be greater than tritium and tritium oxide by a factor of 10 to 100. Hence, surveillance of krypton 85 may provide a useful control index for both. Where iodine 131 and tritium may be released to the atmosphere, the surveillance media of first importance would usually be milk from dairy animals grazing in the area surrounding the nuclear facility. Of the two nuclides, the iodine 131 would be expected to be the controlling factor around nuclear reactors. In the event dairy animals are not grazing, or the release is composed primarily of the shorter-lived iodine radionuclides, the inhalation thyroid dose may be of major importance. Depending on the character and volume of plant wastes and the meteorological and topographical conditions, the area affected may be a few miles to several hundred miles distant from the plant.

Samplers for airborne particulate radioactive wastes are many but representative sampling of the atmospheric environ is extremely com-

plex and would normally involve an exorbitant number of sampling locations. A more realistic approach is to limit the locations along established perimeters of the plant and reduce the sampling and analytical load by gross screening and/or compositing of samples. As the average concentrations of particulate radionuclides approach limits of safety regulations, the size distribution of respirable particulates should be given consideration (*27–29*).

Sampling Equipment

Particulate samples are normally collected on a filter medium in conjunction with an air pump and a flow-measuring device. In this way, the sample is deposited in a uniformly thin layer which is suitable for direct alpha and beta measurement and for gamma spectrometry. For efficient measurement of alpha activity, porous collecting filters and heavy dust loadings should be used. The above samples can be further used in part or in whole as a source for subsequent individual or composite subsamples for radionuclide analysis, particle size studies, autoradiography, and the like.

Membrane filters of pore size 0.8 to 3 microns in diameter are the preferred media. They provide a fairly constant flow over a wide range of filter loadings.

The most satisfactory air movers are positive displacement pumps. Vane pumps are more suitable for use with filters when the head losses exceed 25 or 30 cm of mercury.

Selection of sampling equipment is dependent on the details of measurement procedures. For routine gross alpha and beta measurement with inexpensive scintillation or proportional counters (*30, 31*), samples of 30 to 70 m^3 on a filter area of 10 to 15 cm^2 are acceptable. However, since gamma-spectrometric analysis may also be required, a more useful sample would be 500 m^3 or more per day. Alternately, small samples may be utilized for the gross assays as above, with a larger sample of 2,000 m^3 available for gamma-spectrometric analysis. In this case, an 8- by 10-inch filter, such as the MSA 1106 BH glass fiber filter, is suggested (*32*). A glass fiber filter 3.5 inches in diameter is recommended when neither alpha assays nor gamma spectrometry is required. More detailed information on filter media characteristics is given in the appendix on page 25.

The surveillance of facilities from which nonparticulate radionuclides may be released requires special techniques. For the sampling of gaseous molecular iodine 131, an activated carbon canister placed between the filter and pump is recommended. For this, a canister satisfying U.S. Bureau of Mines Approval No. 2306 is suggested (*33*).

Each of the above sampling systems should be provided with a vacuum gauge and flow meter which, with the sampler, is mounted in

an all-weather shelter with the sampler discharge located so as to prevent the recirculting of air.

For monitoring gamma-emitting nuclides such as argon 41, dosimeter-type photographic film (*26*), thermoluminescent detectors (*25*), and ionization chambers (*34*) hold promise of being gross external exposure meters which measure airborne gamma emitters, including natural background and fallout.

Sampling Stations

The kind, number, and location of samplers which will satisfy the minimum needs for surveillance depend on a thorough evaluation of plant operation and waste management in relation primarily to local conditions of topography, meteorology, and land use. Assuming the application of regulations as given by AEC (*3*), the need for additional monitoring by the public health authority would be minimal if the authority is furnished regular monthly reports of effluent discharges. In this case, infrequent sampling would be required of the public health authority to satisfy legal responsibilities. On the other hand, when atmospheric sampling is indicated, or during a planned release of unusual magnitude, the following recommendations are given.

Samplers should be placed opposite the major lobes of the wind rose representing at least 75 percent of the total. The samplers should be elevated preferably 3 to 20 feet above ground level. Generally, the samplers should not be closer than 10 stack heights from the plant. As a rough initial guide in establishing a suitable perimeter, one air-sampling station might be considered for each community of over 100 people within a 5-mile radius of the plant and one additional sampling station in each community of over 1,000 within a 10-mile radius. This scheme should be modified as required by the specific use of the land and reviewed annually to evaluate findings in relation to the objectives.

Sampling Frequency

Continuous sampling is recommended. The filters usually should not be changed more than once each workday and at the close of the weekend. The carbon canisters, if used, should be changed weekly on a routine basis or after unusual events. For limited sampling, the period of sampling might be only 1 week out of 2 months, for example.

Alpha and Beta Measurements

Particulate radioactivity on filters should be scanned for unusual concentrations of beta activity immediately upon receipt in the laboratory. Those which have normal activities should be stored

for a minimum of 5 hours (to allow for the decay of radon daughters) and then counted for gross beta in a thin end-window counter. A second count made at least 5 days after collection may be desirable following the decay of the thoron daughter, lead 212.

Filters having unusually high beta activity, excluding natural background, may be presumed to indicate contamination which requires further radionuclide analyses to assess the health implications.

The measurement of long-lived alpha emitters should be made after decay of the thorium series, that is, at least 5 days after sample collection. In some instances, it may be desirable to measure short-lived alpha emitters for purposes such as correcting the initial beta count for naturally occurring radioactivity.

Gamma Measurement

After the last filter from an established 7-day period has decayed 5 days, all of the filters for that week may be assembled and gamma scanned as a group for isotopic identification (*35*, *36*). If low-volume (30 to 70 m^3 day) samples were collected and the nuclides of interest are long-lived, they should be composited over a month or two to provide enough activity for gamma analysis and radiochemical examination (*30*, *37*).

Those individual filters which have high initial beta counts should be examined for gamma activity. The action level for gamma scanning individual daily filters may be derived from experience in any specific locality but it may be expected to exceed 5,000 cpm for a 5-cfm sampler and 1,000 cpm for a 1-cfm sampler both counted within one hour after collection.

Upon receipt, the carbon canister may be gamma scanned for radioiodine. Those canisters which have no detectable activity may be reused if they are in good physical condition.

SURVEILLANCE OF WATER

Guides

AEC regulations stipulate the limiting concentrations of a radionuclide or mixture of radionuclides permitted in the liquid waste effluents of nuclear facilities (*3*, *7*). The limit for soluble strontium 90 is 300 pCi/liter and the limit for soluble radium 226 is 30 pCi/liter (*3*, *7*). Consequently, a substantial degree of dilution and natural or artificial purification would be required before these effluents would meet the recommended drinking water standards of 10 pCi/liter for strontium 90 and 3 pCi/liter for radium 226 (*8*).

Waters which receive plant effluents may have multipurpose uses such as commercial and game fishing, domestic animal water supply,

irrigation, manufacturing and public water supply. Each of these uses may be affected by nuclear wastes and the surveillance of water quality is usually a more efficient plan than extensive testing of the many media which might be affected. This condition is emphasized for effluents where dilution reduces the pollution to negligible concentrations. In this case, only the plant effluent records and limited examinations of the receiving water are suggested. On the other hand, pollution which approaches the limits of guides and regulations will require more extensive surveillance of the materials affected.

Underground water supplies may contain high natural radioactivity (radium, radon, and thoron) or may carry radionuclides leached from liquid or solid waste storage tanks and burial areas. Hence, surveillance of ground water commensurate with the pollution potential is important.

Sampling

For routine surveillance of surface waters, daily grab samples composited into weekly samples are usually sufficient. In instances such as for the sampling of large impoundments, less frequent sampling is required. At least one liter of water should be collected each time. The primary stream sampling stations should be located both above and below the nuclear facility effluent discharge, and downstream preferably at the intake of the first water user, with due consideration given to representative sampling. The finished water of this user should also be examined periodically. Sampling stations for well, spring, and cistern waters should be located preferably at the source before potential changes in the water quality have occurred.

Analysis

The samples of turbid raw water should be separated into filtrate and nonfilterable residue before a change in quality occurs (*37*). Gross beta and gross alpha measurements of each fraction are used in the preliminary assay of excessive "slugs" of pollution which, when they occur, are examined for specific nuclides such as by gamma spectrometry with or without radiochemical separation. The filtration step is performed because nonfilterable residue would usually be removed from potable water by conventional water purification, whereas the radioactivity in both the nonfilterable and filtrate fractions may be involved in the multipurpose uses of the water resource.

The routine samples that are not analyzed separately for specific radionuclides may be stored and composited into two 3-month samples for analyses of radionuclides that contribute substantially to the total radiation of the mixture of radionuclides. It is suggested that filtrate samples be composited in those instances where volatile radionuclides

such as tritium may be a component. Tritium is then determined on the distillate of the sample.

Interpretation of Results

The weekly gross beta analyses should indicate whether further gamma or radiochemical determinations are needed in the surveillance program. Monthly gamma analysis and quarterly radiochemical determinations will indicate changes of relative amounts of specific nuclides.

The persistent increase in significant radionuclides is sufficient warning to make inquiries about the cause. If the concentration approaches the recommended limit, a reappraisal of the total exposure is advisable, and appropriate remedial measures should be applied, if necessary. Final determination that a water supply or water resource is contaminated requires knowledge of the individual radionuclide content, rather than gross assay alone. The primary function of the gross activity measurements is to provide an index as to whether further analysis is necessary to identify specific contaminents.

SURVEILLANCE OF FOOD

An *ad hoc* committee convened by the Food and Agriculture Organization of the United Nations considered potential contamination of human food supplies by various applications of atomic energy (*21*). This report discusses in detail foods of terrestial and aquatic origin, sources of contamination, food chains, the hazard of strontium 90 intake in relation to the abundance of calcium, the importance of diet consumption data, and remedial measures. The reference material is highly pertinent to the consideration of the surveillance of food in the vicinity of nuclear facilities.

Guides

The Federal Radiation Council has established guidelines for human intake of strontium 89, strontium 90, iodine 131, and radium 226 (*4*). Three graded scales of action are recommended. They are based on the average intake for a period of 12 months. Individual daily values, which may fluctuate widely from day to day, are of less concern. For fallout from nuclear weapons tests, the intake from ingestion of drinking water or from inhalation has been small in comparison to that from food. This order of relationships, however, may not be the case for wastes from nuclear facilities.

Each of these principal sources from local origin should be considered in relation to the total exposure including worldwide fallout (*38*). The ranges of daily intake and the recommended action to be taken are shown in table 3.

Table 3. Federal Radiation Council guidelines on ranges of rates of intake of radionuclides by people

Radionuclide	Transient rates of intake (picocuries per day) for use in graded scale actions [a]		
	Range I	Range II	Range III
Radium 226	0–2	2–20	20–200
Iodine 131	0–10	10–100	100–1, 000
Strontium 90	0–20	20–200	200–2, 000
Strontium 89	0–200	200–2, 000	2, 000–20, 000

[a] Graded scale of actions is:
Range I: periodic confirmatory surveillance as necessary.
Range II: quantitative surveillance and routine control below the upper limit of the range.
Range III: evaluation and the application of additional control measures as necessary.

For guidance on radioactivity levels in foods due to radionuclides other than those considered by the Federal Radiation Council, the values for maximum permissible concentrations (MPC) in water supplied by the National Committee on Radiation Protection for a 168-hour week may be applied with suitable reservations (*6*). Precautions to be exercised are contained on page 21 of Handbook 69 which reads, "The $(MPC)_w$ values listed in table 1 may, with caution, be applied to foods but to use the $(MPC)_w$ for the 168-hour week, without correction for actual intake, amounts to assuming that 2,200 grams (average daily intake of water for the standard man) of the individual's food (i.e., substantially all his food) is contaminated at this level, and that this situation will persit for 50 years, or until equilibrium is reached in the body. Obviously, a correction factor to take account of the food intake is needed, but to simply use the ratio of 2,200 grams to the grams of intake of a particular food (e.g., butter) as the correction factor amounts to assuming no other foods or beverages are contaminated. Again, all the factors in the total situation must be considered and great judgment must be used in making such corrections."

Milk Products

Fresh whole milk is one of the most important foods to be examined for contamination(*15*). It is easy to collect and to composite, and methodology on radioactivity examinations is available(*39*, *40*). It is a fairly early indicator of contamination when the cows are grazing on pasture, but may not indicate contamination if a release occurs when the cows are eating stored food. Radiological contamination of milk is limited to the radionuclides ^{89}Sr, ^{90}Sr, ^{131}I, ^{137}Cs, and ^{140}Ba which, when ingested by the cow, are metabolized and secreted into the milk.

The collection of milk samples should preferably be from herds grazing within the expected range of contamination. This is usually assumed to be a distance of 10 miles but may be 2 to 10 times further, depending on waste volume and the wind. A random pooled sample of 1 gallon obtained 1 day each week is recommended for immediate gamma-spectrometric examination and subsequent compositing into a monthly or bimonthly sample for radiochemical analysis. The detection of relatively small amounts of contamination of local origin is cause enough to obtain separate samples of milk from the individual dairy herds in the areas in question.

The most convenient sampling locations are the small- to medium-size pasteurizing plants or local collection stations of a large plant or cooperative. However, the milk from individual dairy farms using farmland located within the area subject to contamination should preferably be available for segregated sampling. In the absence of central collection, the random sampling of individual herds is recommended. The appearance of radioactivity in milk is used as an index to decide what other locally grown crops should be sampled and tested. This information, in relation to the dietary habits of the consuming populace and the intake from nonlocal foods, is used to evaluate the total ingested exposure which is then compared to the radiation guides.

In the absence of dairying or until a relationship between milk contamination and the contamination of other indigenous food crops has been established it is recommended that representative samples of typical land crops be collected and subjected to gamma-spectrometric or radiochemical examinations. Although the principal sampling period is that of harvest, an occasional sampling during the growing period may be warranted if contamination is suspected. Greatest emphasis should be placed on leafy vegetables and grain because they may accumulate radioactivity from stack discharges by way of rainout, dry fallout and wind impingement.

Irrigation of crops by waters containing radioactive wastes may lead to the contamination of food such as garden produce, milk, or animal flesh. Sampling and analysis of this foodstuff should be considered at harvest or possibly during the growing season.

Game fish, fish and shellfish obtained from commercial fishery operations in water potentially contaminated by radioactivity should be randomly sampled and analyzed. The sampling frequency depends on the known quality of the water, the dietary importance of game and commercial fishing, and on the radioactive content of the edible parts. The flesh and bone are the parts of most interest. Large bone is usually excluded from the diet but some of the smaller bones are

accidentally or intentionally eaten. Moreover, the accumulation of bone-seeking nuclides in fish may be a useful indicator of contamination.

SURVEILLANCE OF BIOTA

A miscellany of biota other than food have occasionally been sampled from nonfarming areas to observe the behavior, the distribution and the effects of radioactive wastes. Thus, the thyroids of rabbits or other rodents, the indigenous plants or weeds near nuclear facilities, the plankton and benthos of streams, as well as the organic sludges or sediments, have frequently been sampled and assayed. However, routine surveillance of biota may not be of any importance to public health, depending on circumstances. For this reason, the committee has no recommendations to make concerning them.

SURVEILLANCE OF SOILS

The surveillance of soils provides principally a measure of the reservoir of deposited radioactivity. In the absence of local and tropospheric fallout, soil is the sole source of uptake by plants. The contribution from this source to the radioactivity in human food depends on a number of biological, climatological, and edaphic factors. Considerable research is required to relate these factors adequately to human exposure (*41*). Therefore, examination of soils, at the present, should not be undertaken in routine surveillance but only as a research study with the intent of determining long-term trends and changes (*42*, *43*).

SURVEILLANCE OF PRECIPITATION

The deposition of radioactive airborne material from local sources may be by precipitation (rain, snow, hail) and by the sedimentation or wind impingement of dry particulates on the ground and on surfaces (trees, shrubs, grass, land, and so forth). Generally, precipitation is a recognized mechanism in worldwide fallout and it may be presumed to have some effect on the deposition of local releases. Consequently, rain collectors may provide an efficient method of accounting for local deposition. Contamination of the samples from airborne soil or surface dust may be minimized by locating the sampling stations on the roofs of buildings.

Collectors which are serviced after each precipitation provide relatively pure samples of radioactive material from which an accurate measurement of total deposition can be made. Such measurements,

corrected for a nominal amount of runoff, usually yield good estimates of residual deposition.

Although rainfall is relatively easy to collect, snowfall is difficult and windbreakers surrounding the collector are recommended.

A characteristic of young fallout material, which is assumed comparable to that of stack gas effluents from nuclear facilities, is its tendency to be associated with particulates or to become attached to the surfaces of a collector. A method suggested to take advantage of this characteristic is the collection and measurement of nonfilterable radioactivity.

During normal operations of a nuclear facility, when a fraction of the regulatory limits for radiation protection are released to the atmosphere, only a limited amount of sampling is necessary. It would be important, however, to have precipitation collectors in service as convenient samplers for rapid measurement of deposition following planned or accidental airborne releases.

Sampling Equipment

The preferred size of the collector depends on the size of the sample desired, the amount and frequency of precipitation, and the magnitude of expected storms. For the areas having 2 to 10 inches of rain per month, a collection area of 0.1 to 0.2 m^2 is suggested. In the preferred system, the rain is filtered through a sheet of filter paper forming a bottom area equal to that of collection. The filtrate is passed directly through a mixed-bed ion exchanger column to waste. A measuring device such as a tipping bucket and counter would obviate the measurement of liquid volume.

Sampling Stations and Frequency

For plant effluents in excess of AEC regulations or FRC guides, precipitation collectors should be provided at each of the atmospheric sample collectors. After each precipitation or each week the nonfilterable deposition may be tested *in situ* in the field by means of a sensitive survey meter. Following measurable deposition at one or more stations, the filters are replaced and the samples taken to the laboratory for further examination.

Analysis

The filters showing measurable deposition are combined by folding each and stacking to obtain efficient counting geometry on a 4- by 4-inch NaI crystal for gamma spectrometry, or the sample is prepared for radiochemical examination of the residue on ignition, which may uniquely differentiate local contamination from worldwide fallout.

A monthly composite sample or samples of nonfilterable residues combined with the residue from ignited ion exchange resin are analyzed

for alpha-, beta-, and gamma-emitting radionuclides of potential local origin.

Interpretation

By studying the degree of contamination of local food products, especially in relation to the deposition as observed in precipitation collectors, a pattern of distribution may be developed whereby a potential problem arising from known local releases can be predicted. Generally, these predictions are applicable to the specific locale where the multifold factors of meteorology, topography, agriculture, and farming practices cause a varying behavior for different kinds of radioactivity releases from point sources.

THE MEASUREMENT OF RADIOACTIVITY IN PEOPLE

The measurement of radioactivity in people is primarily useful for surveillance purposes following the accidental contamination of the environment. Definitive information relating concentrations of radioactive materials in environmental media to body burdens is needed to substantiate existing radiation protection guides (*5*). Consequently, tentative plans of action for emergency operation are apropos but should be disassociated from a particular industry and probably conducted under the auspices of a research institute.

Emergency planning and background information are important to the success of such an undertaking. Consequently, the following suggestions are presented for consideration.

Two types of human measurements are available—*in vitro* and *in vivo*.

In vitro testing of blood, urine, exhaled air, teeth, and hair may have special merit, particularly for alpha- and beta-emitting nuclides. The technique of removing external radioactive contamination from some of these samples may be a problem, however.

In vivo testing is attractive for measuring gamma-emitting nuclides because individuals can rest in properly shielded rooms while sensitive gamma-scintillation spectrometers record the presence or absence of a large number of radionuclides in different parts of the body. For example, gamma-scintillation detectors are oriented near the thyroid for a measurement of iodine 131 uptake.

The design of representative *in vivo* and *in vitro* sampling on a statistically random basis for one or more strata from the population area of interest may present problems of collection which are neither

feasible nor efficient. An alternate procedure may be designed whereby reasonably unbiased samples from the area of interest may be procured from volunteer clients or patients while they are obtaining services at health centers such as hospitals.

Frequency of sampling

When circumstances indicate the need of measurements of radioactivity in people, the seasonal sampling should be such that the annual sample is large enough for comparison with previous or succeeding annual samples. For example, biweekly or monthly samples may be of value primarily when the environmental pollution is judged to be approaching a degree that requires more careful control. Conversely, accidental contamination may require sporadic sampling of high intensity immediately following the accident with limited followup sampling thereafter.

Analysis

In the case of gamma emitters, the samples or individuals are counted with low-background gamma-scintillation spectrometers. In case more than a few nuclides are detected on the spectra, electronic computer techniques are recommended for resolving the radionuclide content by multilinear (matrix) equations. For alpha- and beta-emitting nuclides the *in vitro* samples are prepared and analyzed as biological (food) samples.

Interpretation

The *in vivo* and *in vitro* radioactivity may be used to derive body burdens and compare them directly with permissible values given by FRC (*4*) and NCRP (*6*).

REFERENCES

(*1*) Cowser, K. E. Current practices in the release and monitoring of I^{131} at NRTS, Hanford, Savannah River, and ORNL. ORNL–NSIC–3, p. 111 (August 11, 1964), CFSTI, Springfield, Va. 22151.

(*2*) United Nations Scientific Committee on the Effects of Atomic Radiation. Report to General Assembly Official Records, 17th Session. Supplement No. 16 (A/5216), United Nations, New York, N.Y. (1962).

(*3*) U.S. Atomic Energy Commission. Rules and Regulations, Title 10, Code of Federal Regulations (January 1965). Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

(*4*) Federal Radiation Council. Background material for the development of radiation protection standards. FRC Report No. 1, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (May 1960).

(*5*) Federal Radiation Council. Protective action guides for strontium-89, strontium-90 and cesium-137. FRC Report No. 7, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (May 1965).

(*6*) National Committee on Radiation Protection. Maximum permissible body burdens and maximum permissible concentrations in air and in water for occupational exposure. National Bureau of Standards Handbook 69, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (1959).

(*7*) U.S. Atomic Energy Commission. Standards for protection against radiation. Federal Register 10CFR Part 20, p. 10170, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

(*8*) U.S. Public Health Service. Public Health Service drinking water standards. PHS Publication No. 956, Revised 1962, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

(*9*) International Commission on Radiological Protection. Radiation Protection Recommendations as Amended 1959 and Revised 1962. ICRP Publication No. 6, Pergamon Press, The Macmillan Company, New York, N.Y. (1964).

(*10*) U.S. Congress Joint Committee on Atomic Energy. Hearings on industrial radioactive waste disposal, January 28, 29, and 30, February 2, 3, 1959. Volumes 1–4, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

(*11*) Tsivoglou, E. C., and R. L. O'Connell. Waste guide for the uranium milling industry. Technical Report No. W62–12, The Robert A. Taft Sanitary Engineering Center, U.S. Public Health Service, Cincinnati, Ohio (1962).

(*12*) The Robert A. Taft Sanitary Engineering Center. Process and waste characteristics at selected uranium mills. Technical Report No. W62–17, The Robert A. Taft Sanitary Engineering Center, U.S. Public Health Service, Cincinnati, Ohio.

(*13*) American Standards Association. American standard radiation protection in uranium mines and mills. ASA N7.1, American Standards Association, Inc., 10 East 40th Street, New York, N.Y. (1960).

(*14*) American Standards Association. American standard radiation protection in nuclear reactor fuel fabrication plants. ASA N7.2, American Standards Association, Inc., 10 East 40th Street, New York, N.Y. (1963).

(*15*) Food and Agriculture Organization of the United Nations. Organization of surveys for radionuclides in food and agriculture. FAO Atomic Energy Series No. 4, Food and Agriculture Organization of the United Nations, Rome (1962).

(*16*) Food and Agriculture Organization of the United Nations. Agricultural and public health aspects of radioactive contamination in normal and emergency situations. FAO Atomic Energy Series No. 5, Food and Agriculture Organization of the United Nations, Rome (1964).

(*17*) Straub, C. P. Treatment and storage of high-level radioactive wastes. Proceedings of the symposium held by the International Atomic Energy Agency in Vienna, October 8–12, 1962. International Atomic Energy Agency, Vienna (1963).

(*18*) Belter, W. G. Advances in radioactive waste management—its effect on future U.S. nuclear power industry. Third United National International Conference on the peaceful uses of atomic energy, A/Conf./28/P/868, Geneva, August 31–September 9, 1964. United Nations, Geneva.

(*19*) Bolles, R. C., and N. E. Ballou. Calculated activities and abundance of U^{235} fission products. U.S. Naval Radiological Defense Laboratory, Paper No. 456 (August 30, 1956), CFSTI, Springfield, Va. 22151.

(*20*) Snyder, W. S. The distribution of ^{239}Pu in the body following exposure by inhalation. Health Physics 10: 1035 (1964).

(*21*) Food and Agriculture Organization of the United Nations. Radioactive materials in food and agriculture. FAO Atomic Energy Series No. 2, Food and Agriculture Organization of the United Nations, Rome (1960).

(*22*) Straub, C. P. Low-level radioactive wastes, treatment, handling and disposal. U.S. Atomic Energy Commission, Division of Technical Information, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (1964).

(*23*) National Academy of Sciences—National Research Council, Committee on Oceanography. Disposal of low-level radioactive waste into Pacific coastal waters. NAS–NRC Publication No. 985, National Academy of Sciences, Washington, D.C. (1962).

(*24*) National Academy of Sciences—National Research Council. The biological effects of atomic radiation. NAS–NRC Publication No. 551, p. 83, National Academy of Sciences, Washington, D.C. (1957)

(*25*) Edgerton Germeshausen and Grier, Inc. Thermoluminescent Dosimeter. Edgerton Germeshausen and Grier, Inc., 300 Robinhill Road, P.O. Box 98, Goleta, Calif. 93017.

(*26*) Whipple, G. Hoyt and C. E. Barber. Monitoring for noble radioactive gases with photographic film. Conference No. 337–33, International Conference on Radioactive Pollution of Gaseous Media, Saclay, France, November 12–16, 1963.

(*27*) Hatch, T. F. and P. Gross. Pulmonary Deposition and Retention of Inhaled Aerosols. Academic Press, New York, N.Y. (1964).

(*28*) Rosinski, J. and J Stockham. Studies related to radioactive fallout. TID–12333, CFSTI, Springfield, Va. 22151.

(*29*) Bradshaw, R. L. and L. R. Setter. Radioactive particles in the atmosphere at Cincinnati, Ohio. Public Health Rep 73:431 (1958).

(*30*) Setter, L. R., G. R. Hagee, and C. P. Straub. Analysis of radioactivity in surface waters—practical laboratory methods. Bulletin No. 227, p. 35, American Society for Testing and Materials, Philadelphia, Pa. (1958).

(*31*) Setter, L. R. and G. I. Coats. The determination of airborne radioactivity. Am Ind Hyg Assoc J 22:64 (February 1961).

(*32*) U.S. Public Health Service, Division of Air Pollution. Air pollution measurements of the National Air Sampling Network—1957–1961. PHS Publication No. 978, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (1962).

(*33*) Mines Safety Appliances Company. Chemical cartridge for gas fume and pocket type respirators. U.S. Bureau of Mines Ap-

proval No. 2306, Catalogue No. CR–4627, Mines Safety Appliances Company, Pittsburgh, Pa.

(*34*) Shambon, A., W. M. Lowder, and W. J. Condon. Ionization chambers for environmental radiation measurements (high pressure ionization chamber). HASL–108 (February 1963), CFSTI, Springfield, Va. 22151.

(*35*) U.S. Public Health Service, Division of Radiological Health. Radionuclide analysis by gamma spectroscopy. The Robert A. Taft Sanitary Engineering Center, U.S. Public Health Service, Cincinnati, Ohio (March 1964).

(*36*) Heath, R. L. Scintillation spectrometry gamma-ray spectrum catalogue. IDO–16880–1, (TID–4500), Volumes 1 and 2, CFSTI, Springfield, Va. 22151.

(*37*) American Public Health Association, American Waste Water Association, Water Pollution Control Federation. Standard methods for the examination of water and waste water, radioactivity measurements, 12th edition. Part II, American Public Health Association, Inc., 1790 Broadway, New York, N.Y. (1965).

(*38*) Federal Radiation Council. Revised fallout estimates for 1964–1965 and verification of the 1963 predictions. FRC Report No. 6, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (October 1964).

(*39*) American Public Health Association. Standard methods for the examination of dairy products, 11th edition. American Public Health Association, Inc., 1790 Broadway, New York, N.Y. (1960).

(*40*) Food and Agriculture Organization of the United Nations, Joint Who/Fao Committee. Methods of radiochemical analysis. FAO Atomic Energy Series No. 1, Food and Agriculture Organization of the United Nations, Rome (1959).

(*41*) Rivera, J., and J. H. Harley. HASL contributions to the study of fallout in food chains. HASL–147 (July 1964), CFSTI, Springfield, Va. 22151.

(*42*) Alexander, L. T., R. H. Jordan, and R. F. Dever. Strontium-90 on the earth's surface. TID–6567 (February 1961), CFSTI, Springfield, Va. 22151.

(*43*) Food and Agriculture Organization of the United Nations. Organization of surveys for radionuclides in food and agriculture—methods of sampling and preparation. FAO Atomic Energy Series No. 4, Appendix 3, p. 92, Food and Agriculture Organization of the United Nations, Rome (1960).

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APPENDIX

FILTER MEDIA FOR AIRBORNE PARTICULATE SAMPLING

There is a wide selection of filter media used for monitoring the radioactivity of airborne particulate matter. Representative examples of the various media available to the world market have been examined by Lockhart and coworkers(*1*), and others(*2–4*). Filter types vary greatly in characteristics and some of the same type and same stated pore size may differ in performance.

Some of the filter media tested, which gave satisfactory retention of particulate radioactivity having a size of 0.2-micron diameter or more, have been selected for further discussion. These filter media usually have retention efficiencies exceeding 98 percent. Figure 1 shows the vacuum (in centimeters of mercury) required to obtain an ambient face velocity through clean filter media as selected primarily from table 2 and table 6 of the Naval Research Report(*1*). Data on the Millipore filters of 5μ-diameter pore size appear in an article by Lindeken *et al.* (*6*). Four of the filter media, shown in figure 1, are cellulose ester membranes with mean pore diameters of 0.8, 2, 5, and 5μ. The latter two filters are from different manufacturers but the same stated pore diameter. However, their permeability to air particulates differs. Whatman cellulose paper No. 41 has a pressure drop curve midway between the two membrane filters of 5μ-pore size. It also has a comparable tendency to clog.

The clogging tendency is given by the numerical value, in parenthesis, for a clean filter face velocity shown by the position of the arrow. The value is given in hours of sampling (at the clean filter rate) when a 10 percent reduction in the flow rate would have occurred. The measurements were taken in the Washington, D.C., area where filter loading may be presumed to be relatively low. For this kind of pollution, the nonclogging characteristic of the glass fiber filters MSA 1106B and 1106BH appears superior to the other filter media shown, that is, approximately 39 hours of operation would give a 10-percent reduction in the sample volume for a 166 cm/sec. face velocity whereas the next best media shown would produce an equivalent volume reduction at half the face velocity in half the time.

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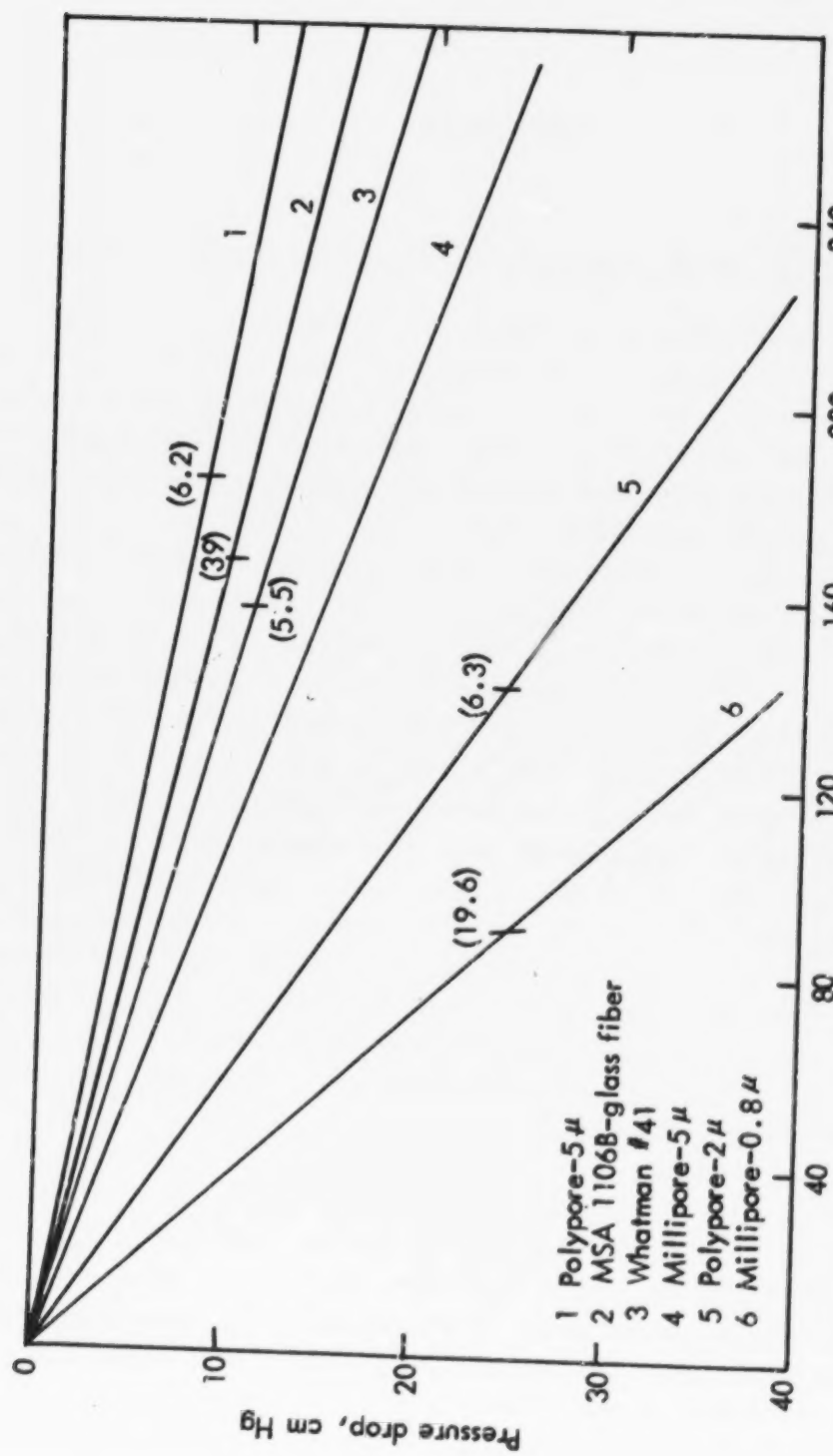

Figure 1. Filter media characteristics (adapted from information in references *1* and 6).
Number in parenthesis is the clogging tendency measured in hours before the clean filter flow rate is reduced by 10 percent.

The selection of a suitable type of filter depends on the kind of radioactivity to be monitored, the instruments available for counting activity, and the purposes of sampling, such as sampling for particulate radioactivity alone multipurpose sampling for radioactivity, and general air pollution, or special sampling for particle size distribution and autoradiography.

For monitoring alpha or beta activity, the smooth flat surface of membrane filters has distinct advantages(*6*). The efficiency of collecting small-diameter particulates such as naturally occurring radon daughters is high, filter absorption is minimal, and particle sizing is practical. Laboratory instrumentation for either alpha or beta assays may be an internal proportional counter accepting samples 2 inches in diameter, or a comparable-size thin end-window proportional counter for beta counting and a zinc sulfide scintillation detector for alpha counting. These laboratory counters with a low alpha background, and a beta background of less than 50 cpm, are adequate for a reliable assay on samples of 25 m^3 or more. A 1- or 2-cfm positive displacement vacuum pump with a membrane filter of 0.8 pore size would be expected to yield a satisfactory sample of about 30 m^3 in 24 hours on a filter area of 10 cm^2. Furthermore, the daily samples could be composited over a month to obtain a sufficient sample for a single gamma assay, and then ignited with alcohol to produce a residue containing only airborne particulate ash for radiochemical examination.

For routine gamma monitoring a much larger sample is preferred so that good resolution can be achieved. Within limits, sample solids and filter media cause relatively minor interference. A practical compromise in sample size appears to be a daily sample of 1,500 to 3,000 m^3. The NASN system of depositing the airborne particulates on glass fiber filters, having an effective area of 7- by 9-inches, provides a sample volume of about 2,000 m^3 with a blower-type air mover (50 cfm) in a 24-hour period under most atmospheric sampling conditions encountered in the United States(*7*). The sampling system could be improved by substituting a positive displacement pump and possibly reducing the collection area. The advantage to be gained in reducing the collection area to an effective filtering area of 3.5 inches in diameter, for example, is that the entire sample could be beta counted in an end-window counting chamber having a window diameter of about 4 inches. The gain in beta counting the larger sample volume would more than compensate for the greater filter absorption and self-absorption losses. For gamma counting, however, the 8- by 10-inch-filter sheet can be folded twice to form a sample deposit which is 3.5 by 4.5 inches, thus providing a geometry quite comparable to a 3.5-inch diameter filter placed on a conventional 4- by 4-inch-gamma-scintillation crystal.

REFERENCES

(*1*) Lockhart, L. B., Jr., R. L. Patterson, and W. L. Anderson. Characteristics of air filter media used for monitoring airborne radioactivity. NRL Report 6054 (March 1964), CFSTI, Springfield, Va. 22151.

(*2*) Fitzgerald, J. J., and C. G. Detwiler. Collection efficiency of air-cleaning and air-sampling filter media. KAPL–1088 (1954), CFSTI, Springfield, Va. 22151.

(*3*) Knolls Atomic Power Laboratory. Radiological development activities in the Health Physics Unit. KAPL–1099 (1957), CFSTI, Springfield, Va. 22151.

(*4*) Smith, W. J., H. F. Surprenant, and A. D. Little. Properties of various filtering media. WASH–170, p. 305 (November 1954), CFSTI, Springfield, Va. 22151.

(*5*) American Conference of Governmental Industrial Hygienists. Air Sampling Instruments. American Conference of Governmental Industrial Hygienists, 1014 Broadway, Cincinnati, Ohio (1962), p. B–2–2.

(*6*) Lindeken, C. L., F. K. Petrock, W. A. Phillips, and R. D. Taylor. Surface collection efficiency of large-pore membrane filters. Health Physics 10:495 (1964).

(*7*) U.S. Public Health Service, Division of Air Pollution. Air pollution measurements of the National Air Sampling Network—1957–61. PHS Publication No. 978, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (1962).

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999–RH–20	Standards of Performance for Film Badge Services
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